Shaft crack detection using the Acceptance Region

One of the major items to consider for life extension of turbogenerators and other plant rotating equipment is the detection of rotor cracks to prevent catastrophic failure.

The primary transducers for observing rotor response to shaft cracks are proximity probes which measure shaft motion relative to the bearing. Two probes should be installed orthogonally (X-Y) at each radial bearing. The primary data for rotor crack detection of an assembled machine is the startup and shutdown data. Particularly important are the 1X and 2X vector responses at various shaft rotative speeds relative to system resonances. Additional information, for example balance condition, steam conditions, alignment, temperatures and other pertinent data should be documented, since they are meaningful for the correct diagnosis of the machine malfunction.

This article describes the method for on-line detection of rotor cracks.

The use of the Acceptance Region for shaft crack detection at operating speed

The change in 1X (synchronous) and 2X amplitude and phase vectors can be monitored on-line, under normal operating conditions, to provide alarms and early warning of shaft cracks. A trend plot in polar format, while the machine is at operating speed, provides an excellent tool for documenting this information. To use this trend plot effectively for each particular machine, normal operating ranges of the 1X and 2X vectors are determined by the appropriate standards (if they exist), or by experience. These ranges should be shown on each plot. A boundary is then set to show the acceptable amplitude and phase extremes of the 1X and 2X vectors.

The boundary extremes will differ for various machines and hence a prior knowledge of likely or acceptable variations will be useful. The region within the boundary is termed the "Acceptance Region". The Acceptance Region has both minimum and maximum amplitude and phase boundaries because a decrease of the trended vector should be as much a concern as an increase.

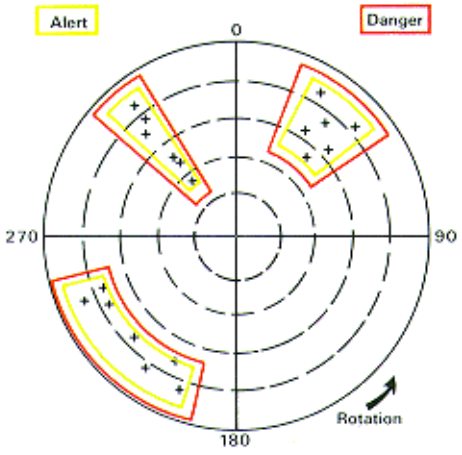

Figure 1

Acceptance Regions can be defined with various boundaries, depending upon the vibration characteristics of each machine under all normal operating conditions.

From "Acceptance Circle" to "Acceptance Region"

Recently, Bently Nevada changed the shape of the Acceptance Region from a circle to a segment (or sector). It was decided that the circle was too restrictive to provide *reliable detection* of rotor cracks. The segment shape allows the vector to change the full amount of acceptable phase with a given amplitude, or likewise vary the full amount of acceptable amplitude with a given phase angle, without leaving the Acceptance Region.

In the circle, if the vector was at its amplitude extreme, then very little phase tolerance would be available before leaving the Acceptance Region. Another advantage of the segment over the circle is that software alarms are easier to define. Bently Nevada's on-line Acceptance Region software provides the capability to set alert and danger levels on maximum and minimum amplitude and on maximum and minimum phase independently (Figure 1).

The 1X vector is *the* most important on-line indicator of shaft cracks.

Deviation of the 1X vector from the Acceptance Region can be a vital warning of a shaft crack (sometimes it is the *only* indicator). It is important to correlate the changes in the 1X vector with changes of the system and process parameters as well as to study (trend) the 2X vector. Correlation of the 1X and 2X vector changes is necessary to determine whether vector changes were caused by a rotor crack or other factors such as load, unbalance, misalignment, field current, steam conditions, or other operating parameters.

Now have your system alarm on deviations from the Acceptance Region

Bently Nevada recognizes the importance of early shaft crack detection. We have published several articles on this subject including January and October 1986 *Orbit* issues. On-line early detection of shaft cracks is provided by Bently Nevada's Dynamic Data Manager® (DDM) system and by our latest product, the System 64, which is described on page 10 in this issue.

Bently Nevada has more than 700 Turbine Supervisory Instrumentation (TSI) systems installed on turbogenerators. While some of these systems have been updated to include computer automated Acceptance Region plotting (by Bently Nevada's DDM or System 64), many knowledgeable plant engineers have been observing and manually plotting trends of this data (using Bently Nevada's DVF 2 or DVF 3, 108 DAI, or Balance Master®) for some time in order to detect cracked rotors at early stages.

Over the last few years, we have received several reports from customers citing instances where Bently Nevada monitoring systems and diagnostic instruments have detected a shaft crack early enough to prevent severe damage to the machine. These machine "saves" have been on various types of rotating machinery including steam turbogenerators, nuclear reactor coolant pumps, reciprocating compressors and engines, and boiler feed pumps.

For more information on early detection methods for shaft cracks, please check RA063 on the reader service card or contact your local Bently Nevada sales representative. ■